DOCUMENT RESUME

ED 060 649 EM 009 690

AUTHOR	Summerlin, Lee
TITLE	A Feasibility Study of Tutorial Type Computer Assisted Instruction in Selected Topics in High School Chemistry.
INSTITUTION	Florida State Univ., Tallahassee. Computer-Assisted Instruction Center.
SPONS AGENCY	Office of Naval Research, Washington, D.C. Personnel and Training Branch.
REPORT NO	TM-39
PUB DATE	26 Jul 71
NOTE	43p.
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	*Chemistry Instruction; Comparative Analysis; *Computer Assisted Instruction; Conventional Instruction; Educational Research; *Feasibility Studies; Instructional Innovation; Program Development; Program Effectiveness; Science Instruction; Secondary School Science

ABSTRACT

A study was performed to determine the effectiveness of short-term, tutorial-type computer-assisted instruction (CAI) in selected topics in high school chemistry. To determine CAI effectiveness, post-tests specifically designed for this study were administered at the completion of instruction and sixty days later. Control group students generally performed 20% higher than did CAI students on both post-tests. The CAI group, however, appeared to learn twice as fast, completing the chemistry program in from one-third to one-half the time required by classroom students. The increased learning rate called for self-pacing and meaningful time usage not ordinarily encountered in traditional instruction; students in CAI felt challenged to productivity. Students were favorably impressed by computer-assisted instruction in general. (RB)

ED 060649

CAI CENTER

TECH MEMO

A FEASIBILITY STUDY OF TUTORIAL TYPE
COMPUTER ASSISTED INSTRUCTION IN SELECTED TOPICS
IN HIGH SCHOOL CHEMISTRY

Lee Summerlin

Tech Memo No. 39
July 26, 1971

Project NR 154-280
Sponsored by
Personnel & Training Research Programs
Psychological Sciences Division
Office of Naval Research
Arlington, Virginia
Contract No. N00014-68-A-0494

FLORIDA STATE UNIVERSITY

009 690

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In terms of substance, these reports will be concise, descriptive, and exploratory in nature. While cast within a CAI research model, a number of the reports will deal with technical implementation topics related to computers and their language or operating systems. Thus, we here at FSU trust this Tech Memo Series will serve a useful service and communication for other workers in the area of computers and education. Any comments to the authors can be forwarded via the Florida State University CAI Center.

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Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Florida State University Computer-Assisted Instruction Center Tallahassee, Florida 32304	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

A Feasibility Study of Tutorial Type Computer-Assisted Instruction in Selected Topics in High School Chemistry

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Tech Memo No. 39, July 26, 1971

5. AUTHOR(S) (First name, middle initial, last name)

Lee Summerlin

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
July 26, 1971	31	25

8a. CONTRACT OR GRANT NO. N00014-68-A-0494 b. PROJECT NO. NR 154-280 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited. Reproduction in whole or in part is permitted for any purpose of the United States Government.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Personnel & Training Research Programs Office of Naval Research Arlington, Virginia

13. ABSTRACT

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(continued on next page)

DD FORM 1473 (PAGE 1)
1 NOV 65

S/N 0101-807-6811

Security Classification
A-31408

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT

DD FORM 1 NOV 65 1473 (BACK)
S/N 0101-807-6821

Security Classification

A-31409

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ABSTRACT

There are no adequately tested, tutorial-type CAI programs currently available at the high school level in chemical education. The problem selected for this study was to determine the effectiveness of short-term, tutorial-type computer-assisted instruction in selected topics in high school chemistry. To determine CAI effectiveness, posttests specifically designed for this study were administered at the completion of the study and 60 days later. Control group students generally performed 20% higher than did CAI students on both posttests. The CAI student group, however, showed approximately a 50% time savings over traditional instruction. Most CAI group students were able to complete the chemistry program in from one third to one half time required by classroom students. The increased learning rate called for self pacing and meaningful time usage not ordinarily encountered in traditional instruction; students in CAI felt challenged to productivity. Student interest in CAI was high; and student attitude toward CAI was generally favorable.

A FEASIBILITY STUDY OF TUTORIAL TYPE COMPUTER-ASSISTED INSTRUCTION IN SELECTED TOPICS IN HIGH SCHOOL CHEMISTRY

Lee Summerlin

Computer-assisted instruction has been advocated by many educators as a valuable tool for facilitating learning. Some educators even consider CAI to be the ultimate in individualizing instruction, allowing the student to receive instruction in a meaningful sequence tailored to his own ability level. More important, perhaps, is the fact that students can progress at their own pace with CAI.

A survey of the literature indicates that computer applications in science instruction have generally followed three paths. The first is the use of the computers in the laboratory, of prime advantage since the computer is a sophisticated problem-solver. Second, computers are used for grading, usually laboratory unknowns (Smith & Schor, 1965; Chappel & Miller, 1967; Young, 1969). The third application, computer-assisted instruction, is an inadequately tested area with a noticeable absence of effective CAI programs, especially in the area of high school chemistry.

<u>CAI in chemistry</u>. Walter Dick (1970) reported 74 existing CAI programs, grades 1-12, currently operative in public schools and under development at various research centers. Of these programs reported,

however, only one was in the area of high school chemistry. Of the more than 300 CAI programs listed by ENTELEK, only eight are in chemistry.

Most of the significant studies in CAI in chemistry are underway at major universities, rather than in public schools or public school systems (Dick, 1970). The only public school system reporting significant CAI in chemistry is Montgomery County, Maryland. Major emphasis in the Montgomery County PROJECT REFLECT (PROJECT REFLECT, 1969a, 1969b, 1969c, 1969d), has been drill and practice or simulation programs in writing and balancing chemical equations, using oxidation potential tables, and computing acid-base titration.

The only other significant efforts at using CAI in high school chemistry are those of Project LOCAL, a demonstration program utilizing resource materials (Slagle, 1969), and Schowalter's CSE (Schowalter, 1970) program. CAI in chemistry finds somewhat wider application at the college level, but few of these programs are of the tutorial type.

Several reasons can be given to partially account for the lack of data regarding CAI programs in chemistry. First, in order to obtain an adequate sample for a computer instruction study, some accepted procedure such as pretesting or randomization must be used. It is difficult to randomly assign students in a public school for an experimental program; such high risk research is generally not condoned in such places. Secondly, many CAI experiments in chemistry are performed in unreal situations, as in a recent study requiring the CAI students to meet from 6-10 p.m., while the control group attended regular lectures (Castleberry & Lagowski, 1970). Thirdly, most existing CAI programs can be completed in a very short period of time. It is most difficult to properly evaluate programs of such short duration. Fourthly, most

existing CAI chemistry programs are used to supplement the regular chemistry program, rather than replace it. Finally, since they are most often used as an adjunct to the regular chemistry program, most CAI chemistry programs are not "tutorial" in nature.

By far, the largest number of CAI programs are drill-and-practice in design. These usually allow the student to develop such skills as balancing chemical equations, writing chemical formulas, etc., generally utilizing the computer as a tireless tutor. There is a need, both as a means for adequate evaluation and as a contribution to the limited field of CAI knowledge, for appropriate tutorial type CAI programs in high school chemistry.

Research Objectives. Recognizing this serious lack of research and development, this study conducted at the Florida State University Computer-Assisted Instruction Center determined to ascertain the effectiveness of a tutorial-type CAI program in high school chemistry, as measured by a suitable posttest. Secondly, the study prepared and evaluated a block of CAI material which could then be made available for use in other high schools. Since there are no adequately-tested, tutorial-type CAI programs currently available, hopefully this would make a significant contribution to chemical education at the high school level. Thirdly, the study examined degree of retention after a 60-day period between those students receiving their chemistry instruction via CAI and those students receiving instruction in the same topics in a more traditional manner. Finally, the study qualitatively estimated economy of time use for CAI as contrasted with usual classroom instruction, and assessed student attitudes toward CAI as a method of instruction in high school chemistry.

Null hypothesis. Null hypotheses are stated only for that portion of the study for which quantitative data can be recorded.

Hypothesis 1: There will be no difference between mean score on a posttest of students receiving chemistry instruction via CAI and students receiving instruction in the same material in a typical classroom manner, when the posttest is given immediately after completion of the project.

Hypothesis 2: There will be no difference between the mean scores on a posttest of students receiving chemistry instruction via CAI and students receiving instruction in the same material in a typical classroom manner, when the posttest is given 60 days after completion of the project.

The Re... rch Design

Campbell and Stanley (1968) design number six was selected for this study. A posttest only, control group design, this does not require a pretest, but asserts that the most adequate all-purpose assurance of lack of initial biases between groups is randomization. It was felt that a pretest on the chemical topics covered in the study would have severely limited internal and external validity of the experiment due to the testing effect. Without a pretest, it was possible to avoid the "give away" repetition of identical or highly similar unusual content, and to control internal and external validity.

Randomization of students. A stratified randomization of students was achieved by listing all students, by class period, in decreasing order of performance on the mathematics and science portion of standardized tests previously taken. These scores were furnished by the guidance office of the University School at Florida State University. Random samples were then drawn from each group, using a table of random numbers (Turney and Robb, 1968).

Posttest design. An adequate posttest, with established reliability, was not available for use with this study. Thus, a posttest was constructed by selecting appropriate test items from a collection of standardized high school chemistry tests. Selection of test items was made from the following examinations: ACS-NSTA Cooperative Examination in High School Chemistry (1959, 1963, 1965, 1967, 1969), Anderson-Fisk Chemistry Test (1966), and CHEM Study Achievement Test (1963-1964, 1964-1965). From these tests, 120 appropriate items were extracted. After checking for duplication in questions, inappropriate or inconsistent nomenclature and terminology, and obsolescence, 60 items were selected for the first posttest. This examination was prepared in two parts, each part consisting of 30 items. Of the remaining items, 35 were selected to be used as a second posttest to be given 60 days after the study.

Procedure. Since suitable CAI programs, of a tutorial type, in high school chemistry were not available, the first task was to prepare the programs to be used with the study. For this project, the following topics in chemistry were selected:

1) Structure of the atom (quantum mechanical model).
2) Chemical bonding (ionic, covalent, van der Waals, hydrogen) and molecular architecture.

These topics were chosen for several reasons. First, these include the topics which seem to give high school students the most trouble; probably because they involve abstract and theoretical concepts which students are often not able to handle. Secondly, these are topics for which entering behaviors are easily determined; that is, students

coming into chemistry usually have no understanding, or at best vague misconceptions, of these concepts. Thirdly, it is difficult to approach these topics from a laboratory-centered approach. Topics that were best taught using a laboratory approach were not included in this study, in order not to risk a deemphasis of the laboratory aspect of chemistry. The topics were chosen also because they lend themselves easily to a tutorial approach, and they provide a sequencing of ideas of suitable length for a CAI program. The total computer program is available on tape from the CAI Center, Florida State University, Tallahassee, Florida.

For each major concept, terminal objectives were determined. Learning hierarchies, as proposed by Gagné (1968) were then established to lead the student to the realization of the stated objectives. A task analysis was then performed to determine, in behavioral terms, the skills which the student must possess, or acquire, in order to progress through the hierarchies and reach the terminal objectives. This approach was taken with each major topic included in the CAI program. The hierarchies for these concepts, the quantum mechanical model for atomic structure, and chemical bonding, and the task analysis for reaching terminal objectives are given in Appendix A.

Designing Course Material for CAI

Several features were built into the CAI program to allow the student to progress at his individual rate. As extensive opportunities for review, two methods were used to present review material to the student. The computer could make this decision, based upon the number of incorrect answers given to a sequence of questions. Each time the student entered an incorrect response, he was given additional or supplementary information and asked to try again. Or, the computer may have elected to return him to that part of the program which his responses indicate that he failed to understand. If he continued to enter incorrect responses to the same question, he was either directed to a reading assignment, a data table, etc., or else he was given the correct answer and continued in the program.

The student could also elect to review. After each series of presentations by the computer, the student was given the option of reviewing or continuing. If he elected to review, he was given supplementary information, explanations using a different approach, or a summary of material presented to that point. The student most often elected a review by simply touching with his light pen the word REVIEW as it appeared on the terminal screen.

The student also had an opportunity to be branched into an advanced track. If his responses were consistently correct, the computer could elect to branch him ahead, skipping much of the drill material. If he later indicated a deficiency in the areas he skipped, he could be branched back.

When replying to the students' responses, every effort was made to protect his ego. Rather than sharply replying NO or WRONG when he gave an incorrect response, he was asked to give the question a little more thought, study supplementary material, and try again. More emphasis was given to rewarding for correct answers.

Extensive use was made of computer-drawn graphics. These were displayed on the screen of the student's terminal. Graphics were used to illustrate double and triple covalent chemical bonding, electron transfer, electron dot structures, geometrical shapes of chemical compounds, electron orbital overlap, formation of ionic solids from atoms, etc. The students could elect to repeat these graphics any number of times.

<u>Preparation of supplementary materials</u>. Materials designed to supplement the CAI program were a flip-pad and a kit of model-building materials. The flip-pad was a 30-page 5" by 7" booklet containing charts, photographs, graphs, data tables, etc., for the student's use with the CAI program. Material used in the flip-pad was taken from the text used in the chemistry course (Choppin, 1970). The same material was available to the control as well as the CAI students. Much of the material in the flip-pad was displayed on the student's terminal screen also; however, the computer would refer the student to the flip-pad when it was necessary for him to study or examine certain figures over an extended period of time.

Each student was also given a shoe-box filled with styrofoam spheres of various sizes and pipe-cleaners for connecting them. The computer directed the student to build styrofoam models to show various

ionic packing arrangements and different atomic and molecular structures. The student was also referred to large classroom-size models and directed by the computer to compare these with those he had constructed. If the student had difficulty building or understanding the models, he could elect to review, and the computer would take him step-by-step through the model building exercises. Large, classroom-size models were borrowed from the chemistry department at Florida State University to be used by the CAI students. A duplicate set of models was made available to the control group of students.

Coding and validating the computer program. The entire program was outlined using IBM 1510 Display Planning Guides. The computer was directed to accumulate the following data for each student: student identification number and terminal identification number; date; each response entered by the student; latency--time required by the student to respond to the computer; total number of correct answers; total time student spent at the terminal; and any other response the student typed into the terminal after he was "signed on." Arrangements were also made to obtain a computer-generated listing of this data for each student. This provided a permanent record of student performance for later data analysis.

Conducting the experiment. A total of 110 students from the University School at Florida State University were involved in the study. They were ranked by class according to their academic ability, divided into upper and lower 50%, and then randomly assigned to treatment and control groups. A table of random numbers was used for selecting students one day prior to beginning the study (Wyatt & Bridges, 1967). There were 58 students in the treatment group and 52 students in the control group.

In order to verify that randomization had produced two similar groups of students, the following procedure was used. Since the beginning of the school year, all students had taken a total of six examinations in chemistry. These exams were multiple-choice, consisting of 25 items, required one hour for completion, and were taken from Tests for Chemistry (Jackson and Summerlin, 1970). All student answers had been recorded on IBM 503 answer sheets and filed. After students were randomly assigned to control and treatment groups, these six examinations were sorted into control and treatment groups. They were then item-analyzed and test-analyzed by computer. None of the six examinations showed a significant difference, at the .05 level, between the scores of the students randomly selected for the control and treatment groups, as measured by a series of t-tests. Thus, it was assumed that randomization had produced two groups of students with similar academic ability.

All students in the CAI group were instructed to report directly to the CAI Center daily during their regular chemistry period for the two week period of the study. They were also told that they could spend as much additional time as they wished on the program (during their free periods, after school, etc.). They were instructed not to return to their regular chemistry class during this period. Once the CAI students began their work, they had no contact with the regular chemistry teacher until they returned to class at the end of the study. There were no absences in the CAI group during the study; all CAI students completed the entire program.

As each student completed the program, he was given the post test. All questions on the post test were of the multiple choice type, and the student selected his answer using CRT light pen. The exact response of each student to each question was recorded by the computer for later data analysis. The CAI students were then asked to complete an attitude survey. This survey, developed specifically for CAI, is a 40 item questionnaire (Brown, 1967). Each question on the questionnaire concerned CAI or the student in relation to CAI, and provided five choices on a Likert-type scale from which the student selected his response.

In order to minimize the Hawthorne Effect, the control group of students were told that they, too, would have an opportunity to work with the computer, but that the other group would "go first". All students in the control group were taught the same material covered in the CAI program. The material covered with the control group included chapters 9, 10, 11, and 12 in the student's text, Chemistry (Choppin, 1970).

Teaching was done in an informal lecture-discussion style, typical of teaching style at the high school level. An overhead projector was used to project visuals usually used when teaching these topics. Extensive reference was made to large classroom models illustrating various types of crystal structures, orbital structures, and geometry of molecules. No films were used and no laboratory work was performed during this period.

Great care was taken to present the same material to all classes. Audio tape recordings were made for each class, each day of the study, to provide a permanent record of material covered with the control group of students.

At the end of the 13th instructional period for the control group, all control group students were given the same post test used with the CAI group. Answers from 60 item post test, given in two parts over a period of two days, were recorded on IBM 503 answer sheets for computer grading and item analysis. All control group students spent three weeks covering the same material included in the CAI program.

Results and Interpretations

After completion of the experiment, student answers were transferred from the computer print-out at the CAI Center to IBM 503 answer sheets for computer grading and analysis. Answer sheets were coded by student number and were submitted together for computer grading, item analysis, and test analysis.

Student achievement. Table I summarizes the computer generated data on performance of the CAI and Control groups of students on the post test given immediately after completion of the study.

TABLE 1

Post Test 1 Data

	CAI Group	Control
Number of Students	58	52
Mean Score	20.66	24.19
Standard deviation	6.49	9.36
KR-20 Reliability	.87	.85
t (from t test)	2.27	

Since the t test for the significance of the difference between means assumes equality of variances, a test for such significance was performed. The difference between variances was not significant at the .05 level.

The calculated group difference t ratio was 2.27. Since the sampling distribution of the difference X_1-X_2 for a sample this large will be very close to a normal distribution, a t value of 1.96 is required for significance at the .05 confidence level. Thus, the data suggest a difference between means which is statistically significant at the .05 level.

Computer generated values of .87 and .85 were determined for the reliability of the post-test taken by the CAI and control students respectively. Reliability was measured by the Kuder-Richardson Formula 20 (KR-20).

Sixty days after completing the study, a second post test was administered to all students. All answers were recorded on IBM 503 answer sheets and these were also machine scored. A computer analysis of this test is given in Table 2.

TABLE 2

Post Test 2 Data
(60 days after study)

	CAI Group	Control
Number of students	58	50[1]
Mean score	10.66	12.62
Standard deviation	4.64	4.64
KR-20 Reliability	.69	.67
t (from t test)	2.15	

Using the same procedure previously described, a t test 2.15 of 2.16 was obtained for this second post test. This indicates a significant difference between the mean scores of the two groups at the .05 confidence level. KR-20 reliability was .69 and .67 for the treatment and control groups, respectively. H'wever, it should be pointed out that this reliability is still well within the acceptable limit. Also, the second post test consisted of 35 items, whereas the first post test contained 60 items. Since the number of test items is a significant factor in determining the KR-20 reliability, these values are within acceptable range.

Results. Null Hypothesis 1: Based upon the data, Null Hypothesis 1 is rejected at the .05 level. The mean score of the control group is significantly higher than the mean score of the CAI group.

Null Hypothesis 2: Data suggests rejection of Null Hypothesis 2 at the .05 level. The mean score of the control group is significantly higher than the mean score of the CAI group.

Student economy of time. In order to provide further data to be used in determining the feasibility of CAI in chemistry at the high school level, a time study was conducted in conjunction with the project. The amount of time required by each student to complete the CAI program, and the number of correct answers recorded for each CAI student during the program was stored by the computer as the student progressed in the CAI program. These data are presented in Table 3.

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1 During this 60 day period, two students in the control group transferred to another school.

TABLE 3

Terminal Time and Number of Correct Responses for Students in CAI Group

Student Number	Number of Correct Responses	Total Terminal Time (in minutes)
R404	347	408
R104	340	232
R301	287	683
R210	251	862
R107	226	264
R101	222	396
R212	219	855
R603	204	425
R201	198	287
R209	195	765
R602	195	768
R204	191	276
R102	181	235
R608	173	235
R307	172	236
R402	159	259
R407	157	351
R306	151	499
R401	148	331
R605	148	209
R302	147	274
R206	138	270
R108	133	266
R409	121	340
R501	120	198
R303	115	232
R502	113	192
R601	112	235
R103	110	290
R105	110	269
R607	109	224
R604	107	220
R106	104	218
R609	104	199
R504	101	210
R203	96	276
R606	92	260
R202	89	262
R208	87	789
R408	84	255
R207	82	724
R406	75	244
R506	74	198

(continued)

Student Number	Number of Correct Responses	Total Terminal Time (in minutes)
R305	73	228
R503	68	198
R405	45	333
R304	36	200
R403	34	530
R505	29	205
R211	25	864
R205	19	192
R109	12	201
R507	12	223

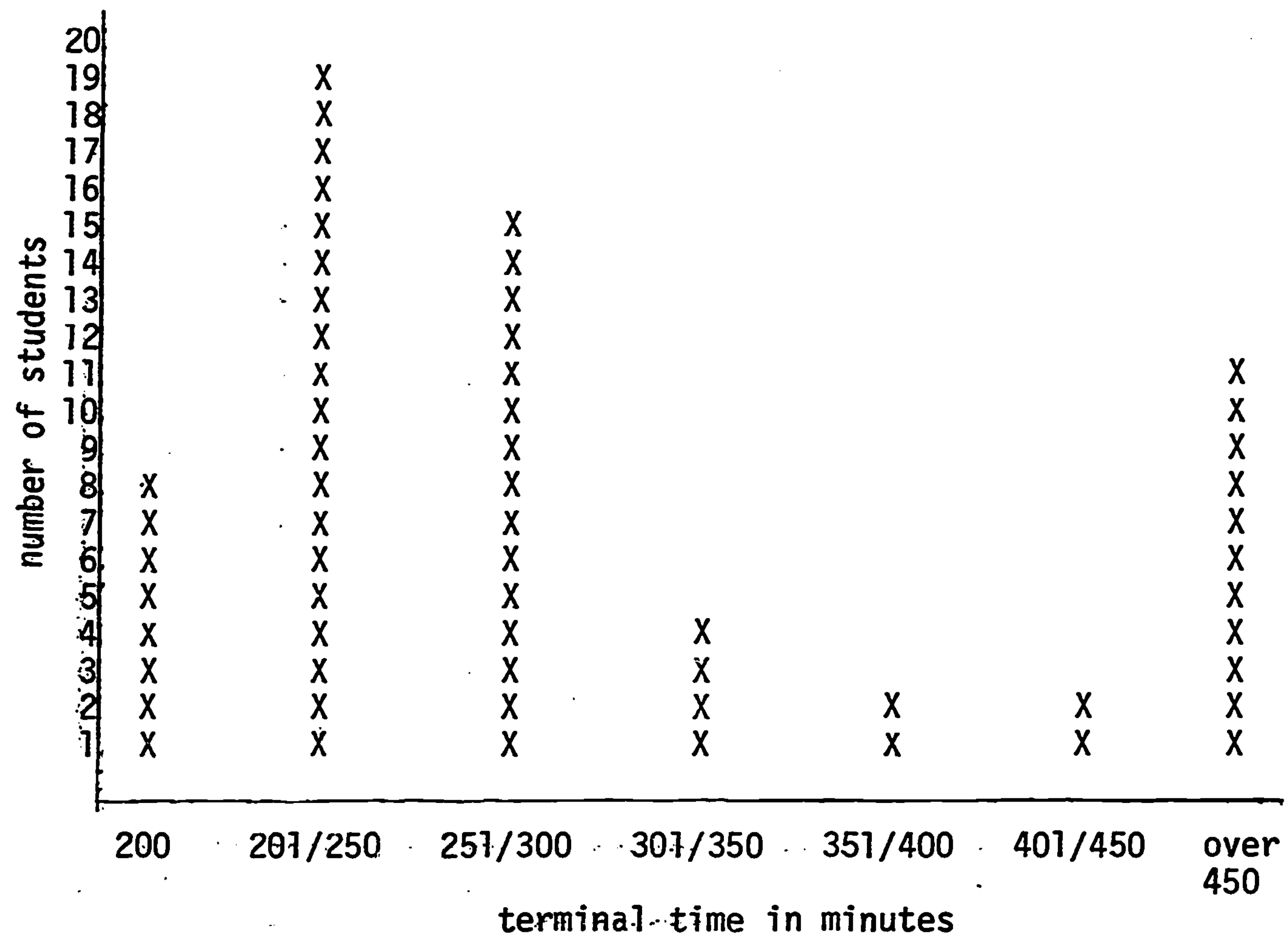
Using the data presented in Table 3, a Pearson-Product moment correlation was calculated to determine if there was a significant relationship between the number of correct responses a student gave, and the length of time he spent with computer assisted instruction.

With this formula, r was determined to be 0.27. This indicates only a modest correlation between the number of correct answers the student gave and the total time he spent on the computer terminal.

A graph of these data, comparing the number of students and the amount of time required to complete the CAI program, is given in Figure 2.

FIGURE 2

Number of students and terminal time



Student Attitude Toward CAI

After completing the CAI program in chemistry, each student was given a 40 item attitude questionnaire. Each statement on the survey provided five choices of responses, on a Likert-type scale. This survey has an established reliability of .86 (Brown, 1967).

Student responses to the survey were recorded on IBM 503 answer sheets and machine scored. A computer generated tally and item analysis gave the percentage of responses to each item, and the total number of students selecting each response. Based upon these data,

the mean scale value was obtained and matched with the nearest associated word on the Likert scale. These results are reported in Table 4. Twenty statements on the survey had a mean scale value near three, indicating a close association with a neutral or indifferent choice on the scale. These statements were not included in Table 4.

TABLE 4

Attitudinal Responses toward CAI

Statement	Mean scale value	Nearest associated word
1. The material presented to me by CAI made me feel that no one cared whether I learned or not	2.2	Disagree
2. The method by which I was told whether I had given a right or wrong answer became monotonous	2.4	Disagree
3. I was concerned that I might not be understanding the material.	4.4	Agree
4. I was more involved in running the machinery than understanding the material.	4.3	Only occasionally
5. I felt I could work at my own pace with CAI	4.1	Agree
6. CAI makes learning mechanical	2.2	Disagree
7. I found it difficult to concentrate on the course material because of the hardware	4.0	Only occasionally
8. CAI made me feel tense	2.0	Disagree
9. While taking CAI, I felt isolated	4.0	Only occasionally
10. The responses to my questions seemed appropriate	2.4	Most of the time
11. Questions were asked which did not relate to the material	4.0	Only occasionally

Table 4 (continued)

Statement	Mean scale value	Nearest associated word
12. CAI is an inefficient use of student time	2.1	Disagree
13. My feeling toward chemistry before I came to CAI was:	2.8	Indifferent
14. My feeling toward chemistry after I came to CAI was:	2.0	Favorable
15. I could have learned more if I hadn't felt pushed	2.3	Disagree
16. Even otherwise interesting material would be boring when presented by CAI	2.1	Disagree
17. I am not in favor of CAI because it depersonalizes instruction	1.9	Disagree
18. I was not concerned when I missed a question because no one was watching me anyway	2.1	Disagree
19. After studying chemistry via CAI I am interested in learning more about the subject matter	3.7	Agree
20. The CAI approach is inflexible	2.4	Disagree

Observations

In addition to the data on student performance recorded by computer and the data extracted from the student attitude survey, student attitudes were recorded during interviews with the proctor and the chemistry teacher.

One of the most consistently reported observations about computer-assisted instruction is that the student may not learn better but he learns faster. The average time required by students to complete the CAI program was 300 minutes, or the equivalent of six class periods.

The control group of students, taught in a more traditional classroom manner, required 15 class periods (750 minutes) to complete the same amount of material. Similar results have been reported with other studies. Students in a computer simulated laboratory program at the University of Texas, for example, were able to complete a 12 hour laboratory program in chemistry in 4.5 hours by CAI (Tabbutt, 1970).

For most students who were accustomed to a lockstep school program of 45 to 60 minutes, regardless of the degree of individualization within that period of time, the idea of really working at their own pace and budgeting their time was a new experience. In this CAI program the students could decide the amount of time they would spend at the computer terminal.

After completing over two week's work in a week or less, many students realized for the first time that they were not making the best use of their time in the classroom. Students suggested that more courses be offered by CAI and that the small chemistry program be expanded to include the entire year's work.

It also became apparent that these students have had little experience in making productive use of their leisure time. It soon became apparent that students wish to be guided into meaningful use of the released time.

The CAI program was generally well received. Most students reported that they were satisfied with what they had learned while taking CAI, and many felt that CAI was superior to traditional instruction. Curiously enough, however, even though they felt that CAI was superior to traditional classroom instruction, most students indicated that they would prefer the more traditional instruction. The reason most often given for this preference was that the teacher has a personality, but the computer doesn't.

The program contained a variety of review and remedial loops which proved to be popular with the students. A check of computer-generated data indicated that most of the students elected to review, when they were given an option of reviewing or continuing. Many students felt that they were not given enough time on certain topics before the computer (based upon student responses) decided to go on to another topic. A large number of students also gave occasional incorrect answers in order to receive the supplementary material which was presented by the computer when it received an answer that didn't match one of the several programmed answers.

Conclusions and Recommendations

Conclusions. The data collected in this study indicate that students learn more, as measured by post tests, with typical classroom instruction in chemistry than they do with tutorial-type computer assisted instruction. There are also indications, suggested by the data, that retention of learned material is greater when learning occurs in the classroom rather than at the computer terminal.

However, this does not imply that computer assisted instruction has no place in the high school program. There are many other factors to be considered when comparing the two methods of instruction. First, the design of the CAI materials in this study was of the tutorial type. Previous reports of greater success with CAI have been reported by Suppes (1968), Atkinson (1969), Snyder (1971), Bobliek (1971), and others. However, all of these programs were of the drill-and-practice type, and were of relatively short duration. It is entirely conceivable that constant drill by the computer, acting as a tireless tutor, will result in increased learning, especially when it is used to supplement, rather than replace, classroom instruction.

There are also other important advantages of computer assisted instruction. The computer effectively treats each student individually, allowing him to progress at his own rate. At the same time the computer can compile a record of his performance and progress, which is immediately available to the teacher. The computer can also give the student immediate feedback concerning his answers. This response time is usually less than one second. Thus the computer allows the student to keep track of his own progress, which is most difficult to do in the classroom.

The study does suggest that a lengthy tutorial type CAI program is probably not the most efficient and effective use of teacher, student, and computer time. Even the most carefully designed CAI program, of the tutorial type, is much more structured than the instruction in the typical classroom. The classroom provides a greater degree of flexibility for the experienced teacher. Secondly, it seems that the entire classroom atmosphere provides the student with the barometer he needs to gauge his success or failure. As indicated by the student attitude survey, this is perhaps missing in the CAI situation where the student is "on his own" with the computer. It is also interesting that 70% of the students also felt uncertain as to their performance in the CAI program, relative to the performance of other students. It is possible that the student taking computer assisted instruction is a little frustrated because he cannot find his usual position in the classroom "pecking order."

The fact that the CAI students learned the chemistry material faster than the students in the classroom is also important. Data collected in this study indicate that students can complete the same amount of material via CAI in at least one-half the time required by students in the classroom. However, as pointed out by Morgan (1969),

this may be of interest to the psychologist as a dependent variable, but it is not a compelling sales point with schools, which in discharging their custodial function must still use up 100% of the students' fixed school time. In view of this, perhaps CAI would be more effective by providing remedial chemistry material for the slower student and enrichment material for the more advanced student.

One of the major disadvantages of a long, tutorial type CAI program is that it ties up the entire computer facility during the instruction time. Perhaps more realistic is computer managed instruction, where the computer is used only for short periods of time. In this case, the computer will act upon input from the student and make decisions as to which instructional task is most appropriate for that student. Thus, the student will be spending most of his time following the computer's directions, rather than interacting constantly with the computer as his "teacher." This modified form of computer assisted instruction would still deal with each student individually, but would have the added advantage of being able to totally occupy the student's time with instructional activities.

This study, and others, have clearly shown that students like computer assisted instruction. Strong student interest and favorable attitude toward CAI imply that this mode of instruction can be used effectively. Further, it is suggested that the difference between the mean scores on the post tests of the two groups in this study (Tables 1 and 2) is small, and when this is compared with the positive student interest, attitude, and time economy, the positive aspects of CAI outweigh the negative aspects.

Recommendations for further research. This study has raised several basic questions that should be considered for further research. Based upon the data collected, and the ideas generated during the study,

it is recommended that the following studies be conducted:

1) to determine if conditioning to CAI has any effect on CAI student performance. The research reported here involved a lengthy CAI program, by current standards. It is unknown how much of this time is used by the student in becoming familiar with CAI and CAI techniques. The performance of both groups should be compared to the performance of students receiving instruction in chemistry in the classroom.

2) to compare the achievement of students receiving chemistry instruction in the classroom with those students receiving classroom instruction supplemented with non-tutorial CAI. This non-tutorial CAI could include drill-and-practice and simulation. Although there have been some studies made in this area, there is a need for studies with adequate control groups, selected with a minimum of bias.

3) to investigate the effectiveness of CAI chemistry programs, both tutorial and non-tutorial types, designed specifically for the slow learner and the accelerated student as a supplement to classroom instruction.

4) to investigate the effectiveness of student-prepared CAI materials in chemistry. Some work has been done in evaluating student-prepared programmed instructional materials. Perhaps this could be extended into the area of computer-assisted instruction.

5) to study the problem of leisure time created by the use of computer-assisted instruction in the high school program, and the concomitant opportunity for an enriched curriculum.

6) to study the use of CAI in chemistry with the additional use of pre-recorded audio tapes, color slides, and single concept films (commercial and teacher made) built into the CAI program.

7) to investigate the possibility of extending CAI in chemistry into a computer-managed instruction system.

Hopefully, this research has provided some insight into the feasibility of using tutorial-type computer assisted instruction in high-school chemistry. However, CAI is now in its infancy, and a better understanding of the learning process and new developments in computer technology are necessary before CAI can become an integral part of the high school curriculum. It is indeed exciting to be at the frontier of this new era in education.

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APPENDIX A

HIERARCHY AND TASK ANALYSIS FOR

CAI CHEMISTRY PROGRAM

HIERARCHY FOR ATOMIC STRUCTURE

Terminal Objective No. 1: The student will be able to represent electron configuration and draw orbital structures for any element in the Periodic Table

Demonstrate an Understanding of electron configurations

Demonstrate an understanding of orbital shapes

Understand the meaning of ground and excited state

Be able to apply Pauli's Exclusion Principle

Know the meaning, values, and symbols for the four quantum numbers

Understand basic principles of probability

Understand concepts of kinetic and potential energy

Have a basic knowledge of structure of atom (electrons and protons)

HIERARCHY FOR CHEMICAL BONDING

Terminal Objective No. 2: The student will be able to write correct chemical formulas, draw ionic and covalent structures, and predict shapes of covalent compounds and ionic crystals.

↑

Understand the relationship between trends in bonding and position of elements in the Periodic Table.

↑

Understand the meaning of Ionization Energy and the use of the Ionization Energy Table → Understand Ionic Radius, and be able to construct models of various crystal structures

↑

Demonstrate an understanding of ionic bond formation → Define electronegativity and electron affinity

↑

Understand the concept of ion formation.

↑

Show an understanding of the tendency for atoms to gain or lose electrons

↑

Have a basic knowledge of Atomic Structure (Terminal Objective No. 1)

HIERARCHY FOR CHEMICAL BONDING (Continued)

Terminal Objective No. 2: The student will be able to write correct chemical formulas, draw ionic and covalent structures, and predict shapes of covalent compounds and ionic crystals.

Understand the relationship between trends in bonding and position of elements in the Periodic Table.

Understand the different geometrical shapes of covalent compounds.

Show understanding of hydrogen bond formation.

Understand orbital hybridization and be able to sketch hybrid orbitals.

Understand van der Waal bonds.

Define dipole and dipole moment.

Show a relationship between orbital overlap and covalent bonding.

Apply Octet Rule

Understand Multiple covalent bonding.

Show an understanding of the tendency for atoms to share electrons.

Draw Electron dot structures

Have a basic knowledge of atomic structure (Terminal Objective No. 1)

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